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ABSTRACT

Down Syndrome children (N=229), aged 1-83 months, from Australia, Canada, and Germany were tested using the Bayley Scales of Infant Development. Test performances on the Bayley's Mental and Motor scales were not dissimilar, leading to the conclusion that young Down Syndrome children from different countries with relatively comparable standards of health and educational provisions develop at a similar rate. As a group, the Down Syndrome children seemed to take about twice as long as normal children to achieve a particular developmental level. The 707 test protocols of the 229 children did not empirically dictate a specific theory of developmental progression. Linear and logarithmic models could be fitted equally well. The same held true with growth functions fitted to an individual subject's longitudinal data. The most striking result was the large variation of test performances in Down Syndrome children at an early age. Standard deviations were about twice as large as expected from a normal sample at equivalent mean performance levels. This result, along with the early fan-like differentiation of growth curves in children tested repeatedly, was felt to imply that Down Syndrome infants are less protected in their early development by biologically based "self-righting processes" than healthy children. (Author/JDD)

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EARLY DEVELOPMENT OF DOWN SYNDROME CHILDREN

AS ASSESSED BY THE BAYLEY SCALES*

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Abstract

Bayley Test protocols of 229 Down syndrome children between one and 83 months of age, some of them tested repeatedly, were collected from Australia, Canada, and Germany.

Test performances in the Mental and Motor Scales of these three different samples were not dissimilar, and it would appear that young Down Syndrome children from different countries with relatively comparable standards of health and educational provisions develop at a similar rate. For further analysis the data from these three samples were combined.

As a group, Down syndrome children, in comparison to normal children, seem to take about twice as long to achieve a particular developmental level. With this data base of about 707 test protocols, linear and logarithmic growth functions could, however, be fitted equally well. The same held true with growth functions fitted to individual subject's longitudinal data. For further analysis it is suggested that individual growth curves be characterized by their qualitative rather than their quantitative features, then aggregated relative to these features and tested against particular developmental models.

The most striking result was the large variation of test performances in Down syndrome children at an already very early age. Standard deviations were about twice as large than expected from a normal sample at equivalent mean performance level. This result as well as the early fan-like differentiation of growth curves in children tested repeatedly seems to corroborate Kopp & McCall's Scoop Model that implies that Down syndrome infants are less protected in their early development by biologically based "self-righting processes" than is assumed for healthy children.

Zusammenfassung

Bayley-Testprotokolle von 229 Kleinkindern mit Down-Syndrom, von denen einige wiederholt und bis zum Alter von 83 Monaten getestet worden waren, standen aus Australien, aus Kanada und aus Deutschland zur weiteren Analyse zur Verfügung.

Weder in der Mental noch in der Motor Scale des Bayley-Tests unterschieden sich die Stichproben aus diesen drei Ländern in bedeutsamer Weise. Die relativ ähnlichen Gesundheits- und Erziehungsstandards dieser drei Länder mögen ein wesentlicher Erklärungsfaktor für dieses Ergebnis sein. Für die weiteren Analysen wurden die drei Stichproben vereint.

Als Gruppe genommen benötigen Down-Syndrom-Kinder in etwa doppelt so lange Zeit als normale Kinder, um ein bestimmtes Entwicklungsniveau zu erreichen. Auf der Basis der Testdaten der Gesamtgruppe (über 700 Testprotokolle) ließen sich lineare und logarithmische Wachstumskurven gleich gut anpassen. Dies gilt auch für die Kurvenanpassung an die Längsschnittdaten individueller Kinder. Für weitere Analysen wird vorgeschlagen, die individuellen Entwicklungsverläufe der einzelnen Kinder nach qualitativen Kurvermerkmalen zu charakterisieren, diese Kurven dann nach diesen Merkmalen geordnet zu aggregieren und auf ihre Kompatibilität mit bestimmten Entwicklungsmodellen zu prüfen.

Das erstaunlichste Ergebnis war die große Variationsbreite in den Testergebnissen bereits der sehr kleinen Down-Syndrom-Kinder. Die Standardabweichung war etwa doppelt so groß wie bei der Standardisierungsstichprobe dieses Tests mit normalen Kindern auf vergleichbarem mittleren Entwicklungsniveau. Dies und die frühe fächerförmige Differenzierung der Entwicklungsverläufe der einzelnen Kinder entspricht dem von Kopp und McCall vorgeschlagenen "Schaufelmodell" der Entwicklung, nach dem Down-Syndrom-Kinder weniger durch biologisch verankerte "Selbstkorrekturprozesse" in ihren frühen Entwicklungsphasen geschützt sind, als dies bei chromosomengesunden Kindern angenommen wird.

Purpose

Down-syndrome children constitute the largest diagnostic group with early developmental and cognitive deficiency. They can be clearly diagnosed at birth and therefore have become a preferred group of subjects for infant researchers interested in early signs or precursors of developmental problems (Hartley 1986, Lane & Stratford 1985).

A Down-syndrome child can be born into any family. No relationship to social class or other sociodemographic characteristics has been found except for the established fact of a higher probability of having a child with Down syndrome (DS) if the mother is close to or beyond forty years of age, with the father's age having some possible influence, too. (Zaremba 1985). Although Down syndrome (DS) results from a chromosomal aberration (Trisomy 21), there is no evidence that this is hereditary except for those rare forms of Trisomy 21 such as Mosaicism (only a certain percentage of the child's cells carries the triploid 21) or Translocation (a part of the third chromosome 21 is attached to another chromosome), which constitute only 4-6% of all cases with Down Syndrome.

Incidence figures on DS births given in the scientific literature vary from 1:480 live births (Harbauer & Schmidt 1979, Herzka 1978, Rutter & Hersow 1977) to 1:1000 (Rutter & Hersow 1985) with the lower incidence rate presumably reflecting recent "success" in prenatal diagnostics and more lenient abortion laws. In most industrialized countries pregnant women over 35 are advised to undergo amniocentesis or newer forms of prenatal diagnosis and, in the case of a positive result, are eligible for abortion. Nevertheless, the incidence of newborns with DS did not decrease as much as could be expected. Of late, more DS children were born to younger mothers, and, over all, most DS children have mothers younger than 35 years of age.

Thus, Down-syndrome children are still the largest group of mentally handicapped children. They form a specific subpopulation which, however, in most demographic aspects closely resembles the general population, with perhaps a slightly increased maternal age.

Both, the sociodemographic similarity to the general population and the early clear diagnosis are important features which is why students of child development focus their special interest upon these children with questions such as:

- In what respect does their development differ from that of children with normal karyotype?
- Do established models of developmental functions, sequences or structures adequately describe the development of these children?
- Do theories of developmental mechanisms stand the test with data from these children?

The purpose of this paper is to present results regarding the developmental courses in a population of young DS children at a descriptive quantitative level in order to better understand the development of these children, with the intention of proceeding to more detailed and qualitative analyses at some future date. On the other hand, developmental data of this special group of children serves to test the appropriateness of models and methods used in developmental psychology at-large and to develop or to adapt new methods or models, if necessary.

Data Source

Intellectually disabled children are frequently assessed and monitored using standardized tests which were devised for use with non-handicapped children. In early childhood, the Bayley

Scales of Infant Development (BSID) are among the most widely used research and clinical instruments in the assessment of the developmental level and prediction of the further development of normal, of those at-risk, and of handicapped children. The 163 items of the Mental and the 81 items of the Motor Subscale represent the accumulated knowledge of developmentally sensitive achievements in the first 30 months of normal children. The test, its subscales and each item were carefully standardized with 1,400 U.S. children (Bayley 1969). The standardization sample, however, did not include children with known handicaps or sicknesses. A Dutch standardization of the Bayley Scales with normal children is also available (van der Meulen & Smrkovsky 1984). The Bayley Scales themselves have never been standardized with handicapped children.

Bayley test protocols from young Down syndrome children were made available from Brisbane/Australia, Toronto/Canada, and from W. Germany. They were part of separate research and evaluation projects and were not collected for the purpose of either standardizing the Bayley Scales nor for this study.

The purpose of the German study was to investigate the appropriateness of the Bayley Scales for mentally handicapped children beyond the age period for which the test was standardized (Jähnichen 1979, Rauh & Diesch 1987). All Down Syndrome children available in special day care centers in several German cities were included in the sample. At that time, integrated nursery schools did not exist. If there had been a selection, the more poorly developed children might not have attended the day care centers.

A high proportion of all Down syndrome children born in a specific area within a period of 18 months is included in the Australian sample as part of a prospective longitudinal study of DS children and their families (Berry et al. 1984). Some children in the Australian cohort continued to be assessed

using the Bayley Scales for as long as the Scales sampled behavior within the Bayley developmental-age limits, usually until a mental age of about 20 to 24 months. Whenever a child functioned towards the upper limit of the Bayley Scales, other assessment instruments were used, e.g. the Merrill-Palmer or the Stanford-Binet Test.

In Canada, most Down syndrome children within a large urban area could be reached through an early intervention project. Bayley Scales were used for evaluation purposes until the children reached the age of about 30 months, thereafter assessment instruments were changed.

Within the standardization age-range of 30 months, therefore, the data represent total or near total populations in two large urban areas. A great number of the children in Canada and Australia have been tested repeatedly, up to four times and more, thus providing an interesting data basis for longitudinal analyses.

The present data source is unique in that a large population of young DS children has been sampled (n=229). The number of test protocols from DS children (about 700 protocols for each subscale) amounts to about half the number of the Bayley standardization protocols. The data source, however, is also heterogeneous: the protocols come from different world regions, were collected for diverse purposes, and the assessment ages of the children vary. These facts limit regular statistical procedures as well as stimulate analyses which may be better suited for data of this kind.

Research Questions

Our analysis was guided by a consideration of the following four questions:

- (1) Do DS children from different parts of the world resemble each other in their general pattern of development?

DS children are often said to resemble each other more than even their own sisters and brothers. Since the syndrome can be traced back to a single cause, the trisomy of chromosome 21, their developmental characteristics seem to be understood as direct outcome of this aberration. Prototypical characterizations of children with Down syndrome in medical books (e.g. Tolksdorf & Wiedemann 1981) and books for parents (e.g. Rett 1977) also suggest homogeneity in this group of children.

Recent research, on the other hand, ascertained improvements in the level of developmental achievements in these children in the recent decades due to early stimulation and early intervention. These results imply some plasticity in the development of young DS children.

The available test protocols for this analysis are from countries with good health and educational provisions. All children were brought up in families, and all had easy access to early guidance and intervention. Language differences are not supposed to influence Bayley test results since active and receptive speech at this developmental level seem to be very comparable in English and German. The major difference between the countries seems to lie in their respective climates; Canada and Germany have temperate summers and cold winters whereas sub-tropical north-east Australia has winters that resemble nice dry summers in Germany and has hot wet summers. Children in Australia spend most of their time in the open air, lightly dressed. It might be that such a climate is to the advantage

of Down syndrome infants. If there are any differences at all between the groups, Australian children should show advanced motor development.

(2) Is the mean mental development in DS children a linear or a curvilinear variant of the development in normal children?

Zeaman and House (1962) as well as Silverstein (1966) suggested that the mental development of children with Down Syndrome is best characterized by an early nearly normal spurt and a flattening gradient thereafter. Using IQs rather than MAs (Mental Ages) as indicator, Carr (1985) comes to a similar conclusion, namely a steep decrease of IQ after the first year, which is however more pronounced in institutionalized children. Several formulas have been advanced for estimating the mental age (MA') of a DS child given his/her chronological age(CA):

Zeaman & House (1962): $MA'(DS) = 18 * \log(CA)$

Silverstein (1966): $MA'(DS) = 20.87 * \log(CA)$

The general formula would read:

$$MA'(DS) = b * \log(CA) + a$$

(The estimated mental age of a Down syndrome person equals a gradient b times the logarithm of the chronological age plus a constant).

Such a formula is appealing. It does, however, also imply a specific theory of development with the following ingredients:

- Development is continuous but reaches an upper limit early.
- In the early stages, development is similar to but slower than in normal children.
- The more biologically controlled functions characterizing early stages of development are less impaired than are developmental achievements based on learning, mental representation, information processing and language.
- Socialization and educational influences are of little impact.

Based on more recent data of mental performances of children with Down Syndrome, Berry, Gunn and Andrews (1984) suggested that the mean mental age of DS children would best be represented by a linear function, such as

$$MA'(DS) = 0.5 * CA + 3 \text{ months}$$

(The estimated IQ of a DS child would be equivalent to half his/her chronological age plus three months).

Besides being more economical, this formula implies a developmental model with the following features:

- Development in DS children is continuous; no plateau is defined.
- Their development resembles closely that of normal children.
- Similar to normal children, their development appears to be based as well on biological functions as on information processing and learning.
- There is no indication that socialization has no effect.
- All developmental achievements are similarly influenced by the impairments characteristic of Down Syndrome resulting in retarded development.

Recent research with young DS children using Piagetian tasks for assessing sensorimotor development (see Morss 1985) or language development (Gunn 1985) suggests that they eventually progress through the same stages as do normal children with similar cognitive structures and similar stage-typical mistakes. Most authors, however, contend that their motor achievements (Henderson 1985) or their mental structures (Dunst & Rheingrover 1983, Morss 1985, Rauh 1983, Wishart 1987), though superficially similar, take different developmental routes, are less stable, less generalized and less differentiated (Gunn 1985) than in normal children.

The Bayley test protocols will be analyzed to determine whether they conform better to a linear or a curvilinear model of development.

(3) Is the interindividual variation within the group of DS children restricted or extended?

Since DS children belong to one clear diagnostic group and if mental retardation is a direct result from the chromosomal aberration, then their mental performances should be estimated with less error, and test performances within this well defined subgroup should be clearly lower than in the normal population. This contention also implies that mental development and especially mental retardation is strongly biologically controlled.

Kopp & McCall (1982), however, have suggested that Down syndrome may imply a reduced biological control. In normal healthy children as well as in preterm children without clear brain damage, mental development at later ages (five years and later) can hardly be predicted from Bayley Test performances before their third year of life. Adverse experiences as well as sicknesses in these children, if they are not extreme, seem to distort their regular path of development only for a short time. Biologically based "self-righting processes" eventually correct for minor deviations. These "self-righting processes" in themselves, however, become less pronounced beyond the second year of life. Kopp & McCall represent their model of development with a scoop, borrowing from Waddington (1961) who used the same picture in order to explain assimilation in evolution. The form of the scoop represents the self-righting forces; their diminution over age is pictured by the flattening form of the scoop. (Fig. 1) The individual, represented by the ball, passes through the scoop. Any deviation caused either by mistakes in the form of the scoop (perhaps periods of sicknesses) or by external forces (perhaps parental influences) is eventually corrected for by the general form of the scoop. But from the time when the "scoop" becomes nearly flat, interindividual differences become established.

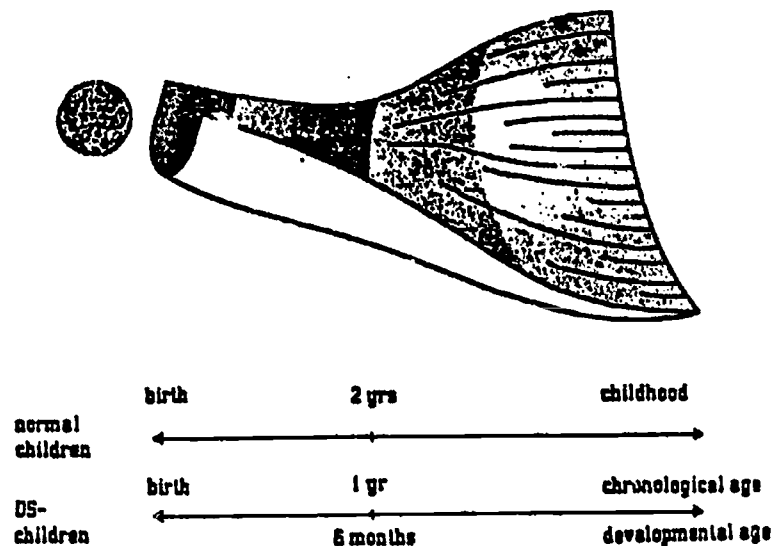


Fig.1: The Scoop Model by Kopp & McCall (1982) representing the diminution of biologically controlled self-righting forces over age in early childhood in normal and DS children.

Down syndrome children, in the model of Kopp and McCall, are characterized by less pronounced "self-righting processes", represented by a scoop that becomes flattened at an earlier age (see Fig.1). This implies that interindividual differences become relatively stable at an earlier age in DS than in normal children. Analyzing the data of DS children, they could show that Bayley Test performances in these children were indicative of later intelligence (five years and later) already at 12 months of age when their average level of performance was little more than that of six months of age. Their model, applied to our data, would suggest a larger variation within the population of DS children than in the standardization sample, implying that DS children at this early age are even more influenced by all kinds of positive as well as adverse experiences and more dependent in their development on optimal stimulation and guidance.

- (4) Do individual growth paths of DS children based on longitudinal data, conform to the growth models abstracted from the group data?

Tanner (1961) as well as Wohlwill (1973) have demonstrated that growth curves derived from group data may camouflage the characteristic features of individual growth curves. They suggested that developmental functions should be aggregated over individual growth curves.

Similar to question (2), individual growth curves may conform to either a linear or a curvilinear model. Furthermore, different children may differ in their growth parameters relative to the severity of their biological or social handicap but still belong to the same group represented by the major characteristics of their growth curves.

It is, however, also conceivable that DS children, although belonging to one diagnostic class, fall into different and distinct subgroups of children as characterized by their growth patterns. Since no such studies have yet been done with normal or other groups of children, no hypothesis about possible underlying theories will be advanced. The idea, however, will be tested with those children where enough repeated assessments (at least six) are available.

Sample

Altogether, 707 Mental and/or Motor test protocols of 229 Down Syndrome children ranging from three to 83 months of age were available for analysis. 58% of the children were boys and 42% were girls. Since no sex differences appeared in the results they are omitted here.

Table 1
The samples of Down syndrome children and assessments
by country

Country	Subjects		Test protocols	
	n	%	n	%
Australia	51	22.3	231	32.7
Canada	146	63.7	444	62.8
W.Germany	32	14.0	32	4.5

As Table 1 shows, 444 assessments (62,7%) of 146 children came from Canada. They refer to infants up to 26 months of age. Australia provided 231 assessments (32,8%) of 51 children, mostly from 6 to 60 months and with three children assessed past this age. The latter children were usually omitted from analyses. The smallest number of protocols (4,5%) refers to 32 German children ranging from 14 to 62 months who were tested only once.

Table 2 gives a differentiated overview of the complex sample composition. The left margin of the table tells how many children were tested one, two, three and up to eleven times.

Each stratum shows the break-up by country. In the diagonal, the number of children for whom at least one, two etc. assessments are available, are listed; these numbers are cumulative from the upper right to the lower left corner. The number of test protocols is the product of the diagonal (number of subjects) multiplied by the respective number of assessments (horizontal).

Table 2:
Sample strata for the analyses at group level (total sample)
and of individual growth functions (r=22)

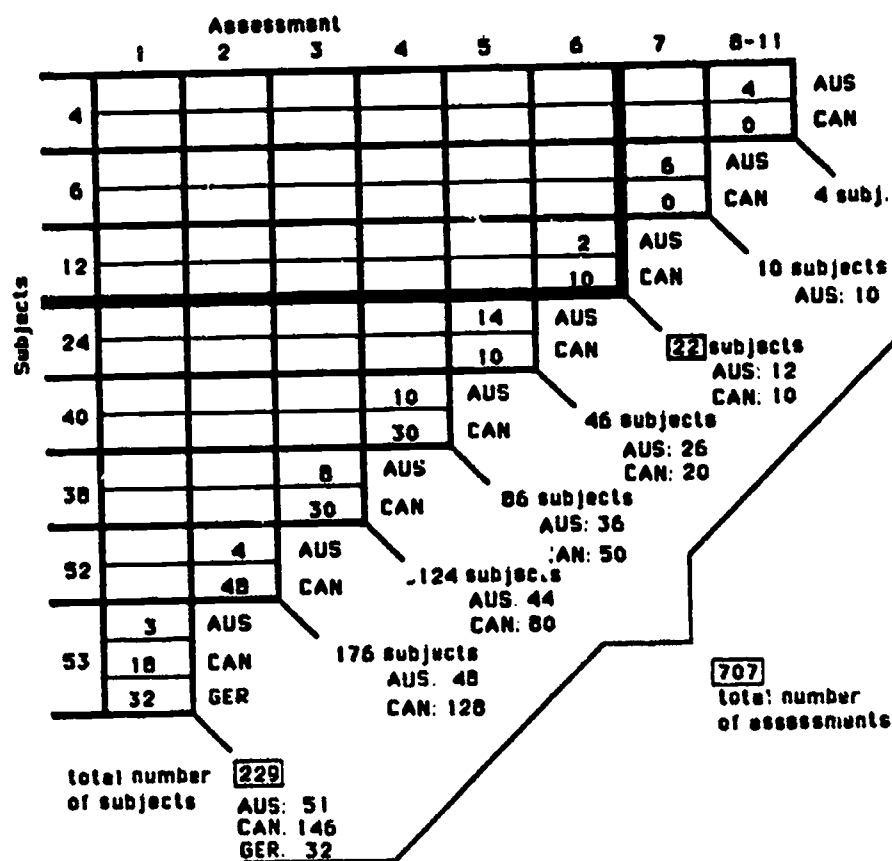


Figure 2 gives the distribution of chronological age of all subjects over all assessments of the Mental Scale (n= 681). A few children were tested with only one part of the test at a particular assessment date, usually due to some kind of unavailability of the child, such as crying. Also, test protocols of those nine children beyond twice the standardization age (61 months) were usually not included in the analyses. The age distribution shows a certain age preference for mental testing with the Bayley Scales with peaks at 12, 18 and 24 months. Fifty percent of all tests cover an age range up to 17 months, and 75% up to 24 months. More than 100 assessments were administered beyond the age range covered by the standardization of the test.

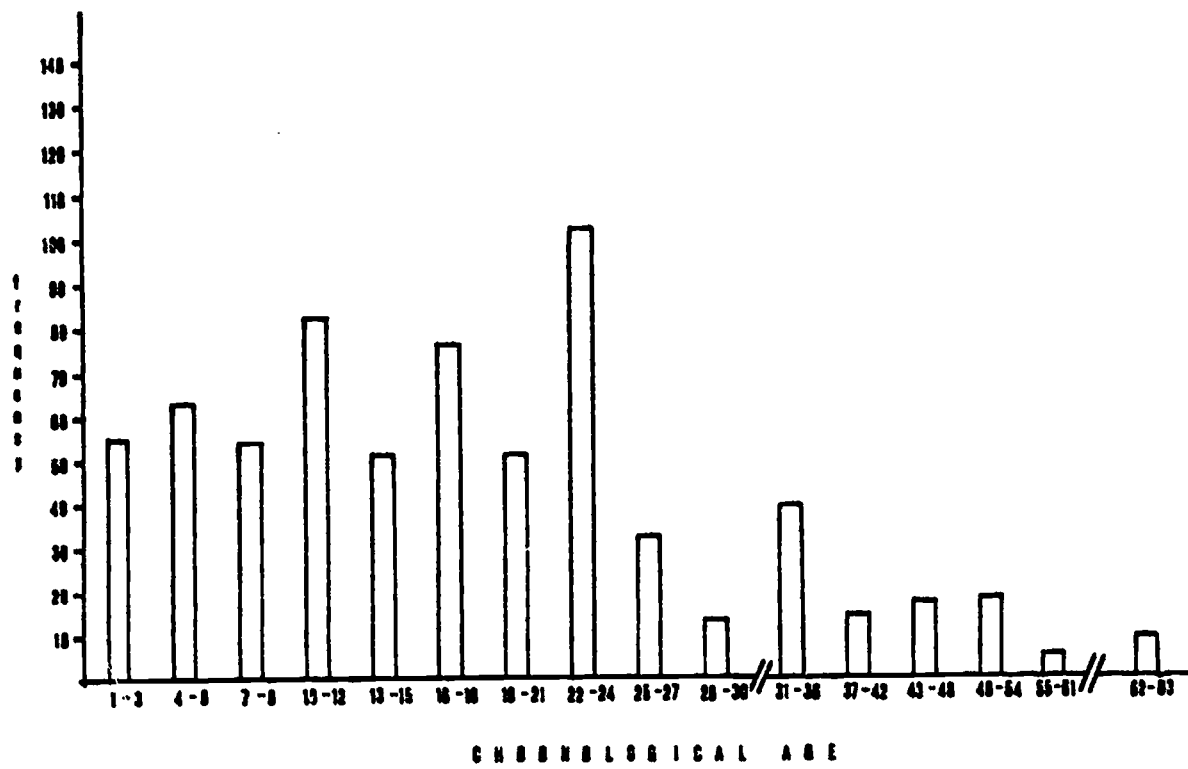


Fig.2: Distribution of test protocols by age of the children

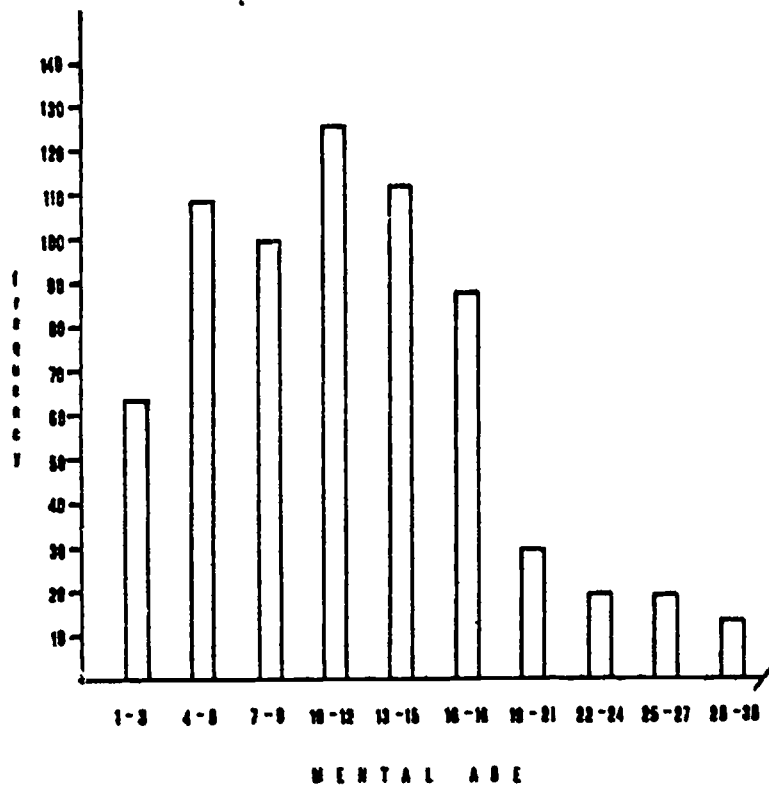


Fig.3: Distribution of Mental age scores over all assessments and subjects

Figure 3 shows the distribution of Mental age scores over all subjects and assessments. The Bayley Scales are standardized in the same manner as the Wechsler Scales. The raw scores of each subscale are transformed by month of chronological age into a Mental or Motor Index, respectively, similar to a deviation IQ with a mean of 100 and a standard deviation of 16. As with the Wechsler Scales, one can read from the norm tables at which chronological age a particular raw score reaches the Mental Index value of 100. This age was used as Mental or Motor age, respectively. If a particular raw score did not exactly coincide with an Index of 100, the age closest to this value was chosen. Transformations into Mental and Motor ages were used for scaling reasons and for comparative purposes. The distribution of Motor ages is similar to that of Mental ages and is omitted here.

Results

Comparison between countries

Different age ranges are covered by the different countries, therefore only pairwise comparisons with Australia were feasible. Since most Canadian children were tested up to 26 months of age and most German children thereafter, two age groups were formed with either 26 months or 30 months (upper standardization age) as demarcation ages. Correlations between Mental or Motor age scores, on the one hand, and chronological age (CA) on the other hand, as well as regression coefficients of Mental or Motor age on CA were compared between the regions.

Tables 3a and 3b give the results of the correlation analysis. For the younger children up to 30 months of age, there are no or negligible differences in correlations between the Canadian and the Australian sample. This is also true for the slope of the regression lines (Tables 4a and 4b) with only a slightly higher intercept in the Australian sample with both, the Mental and the Motor Scale.

For the first 30 months of age, the data of the two groups of Down Syndrome children in Canada and in subtropical Australia are so similar that they can be merged for further analyses. Since the samples are so large and cover almost the entire young DS population of their respective region, these data can probably also be taken as representative of young DS children growing up in families and societies with relatively good health and educational provisions.

For the higher age ranges, comparisons were only possible between the Australian and the German data. Remember that the German sample is probably not representative of DS children at that age in the country, and it is rather small. Differences in the correlation coefficients are not significant for the Mental Scale and fall short of significance in the Motor Scale. In both cases, correlations with chronological age are higher for the German sample. The differences in the regression lines are most marked for the Motor Scale. Although the slope is similar in these two countries, the general level is about two Motor Months higher in the Australian sample. Inspection of the scatter diagrams shows that only very few children in Germany had been tested at ages between 40 and 50 months where quite a few Australian children were covered some of whom reached high scores. Whereas some Australian children scored rather low on the mental scale this was not true for their motor performances. Before attributing this difference to different experiences due perhaps to different climates, caution is advised: The Australian tester omitted some motor items because she lacked some equipment. This may have inflated her scoring. Still, these differences at the upper developmental levels should be kept in mind for further research. For our purposes, we decided conservatively and merged the Australian and German data in further analyses.

Table 3a: Correlations between chronological and Mental age

Age range	Sample	r	n	Difference
0 - 30 months	all	.90	578	
	Canada	.90	438	
	Australia	.87	138	n.s.
31 - 61 months	all	.53	94	
	Australia	.41	64	
	Germany	.62	25	p=.26 (two-tailed)

Table 3b: Correlations between chronological and Motor age

Age range	Sample	r	n	Difference
0 - 30 months	all	.87	536	
	Canada	.87	398	
	Australia	.87	136	n.s.
31 - 61 months	all	.53	103	
	Australia	.49	75	
	Germany	.75	25	p=.06 (two-tailed)

Table 4a: Regression of Mental age on CA by region

Age range	Region	Cases	Intercept	Slope
0 - 26 months	Canada	428	1.0	.58
	Australia	129	1.78	.55
27 - 61 months	Australia	69	11.85	.21
	Germany	25	11.14	.28

Table 4b: Regression of Motor age on CA by region

Age range	Region	Cases	Intercept	Slope
0 - 26 Months	Canada	391	1.29	.49
	Australia	126	1.81	.48
27 - 61 Months	Australia	81	7.37	.35
	Germany	25	5.11	.36

Note that the total number of assessments with each subscale may be less than the total of 707 assessments since some children could be tested with only either the Mental or the Motor subscale at a particular test session. Also, in most analyses the data of children beyond the age of 61 months were not used.

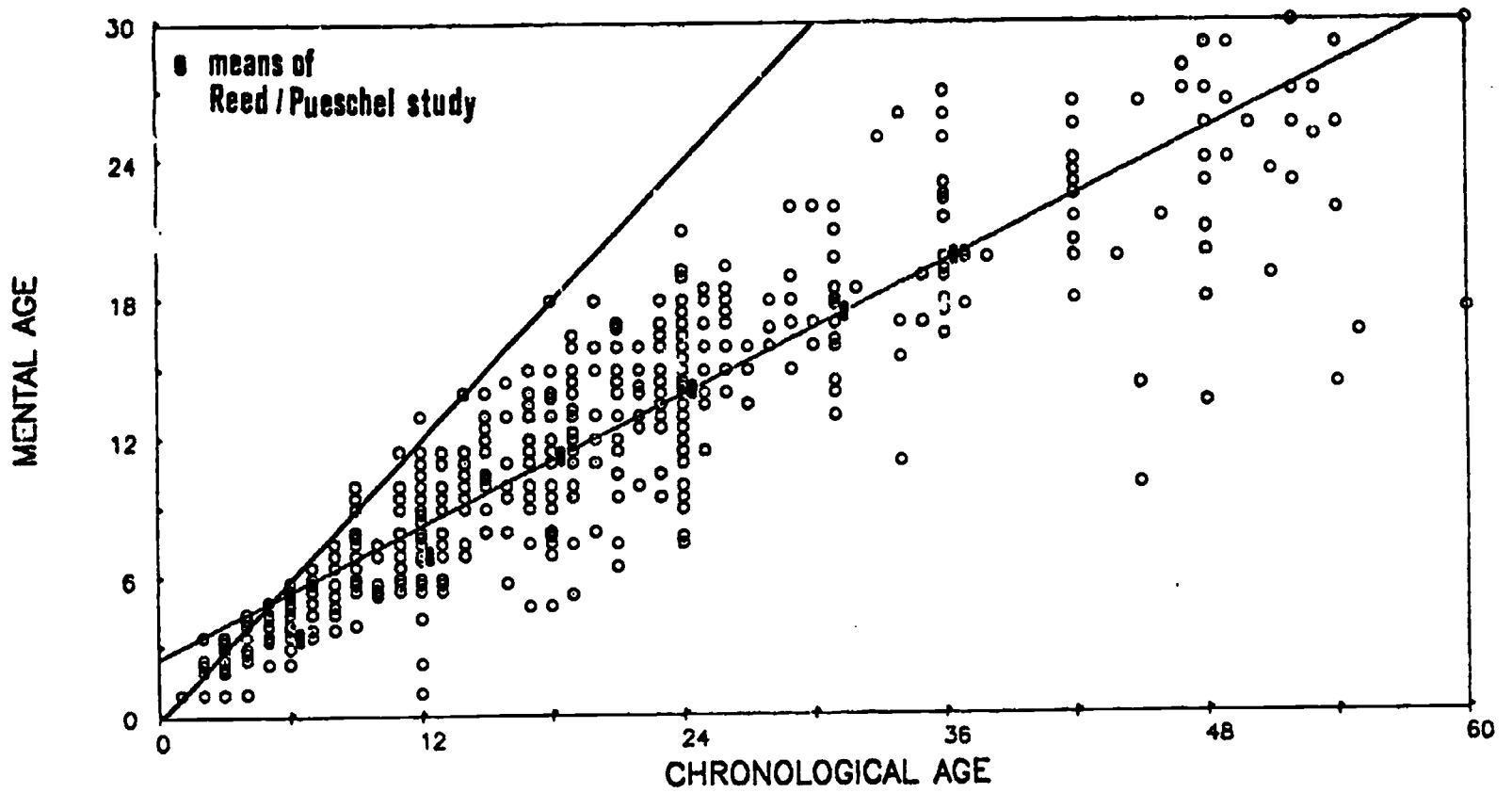


Fig. 4: Distribution of Mental age scores by chronological age (229 Down syndrome children, total of 672 assessments)

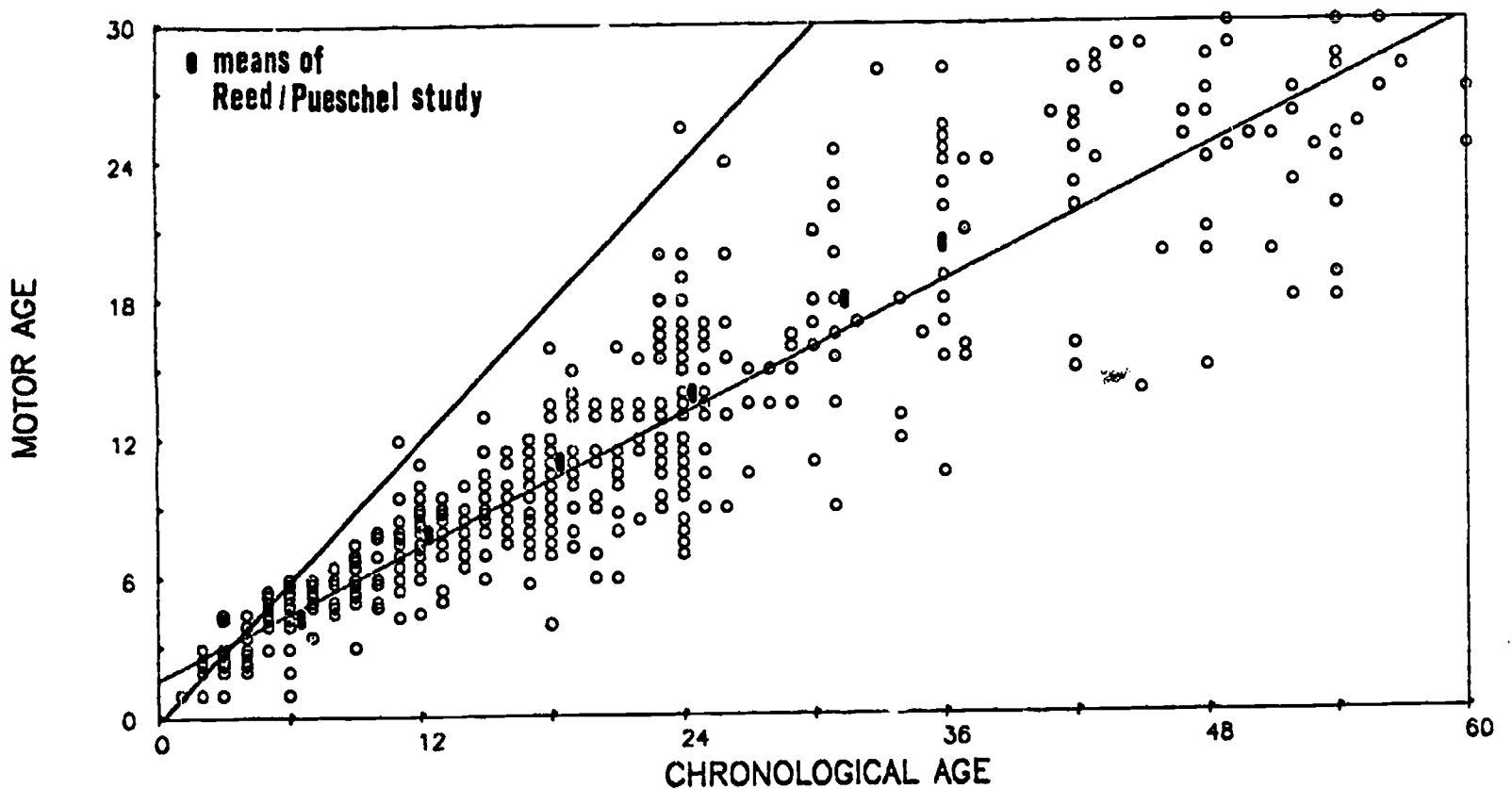


Fig. 5: Distribution of Motor age scores by chronological age (229 Down syndrome children, total of 639 assessments)

The mean Mental and Motor age scores of young DS children in the Boston area in the U.S. studied by Reed, Pueschel et al. (1980, Pueschel 1984) fit well into our data. Figures 4 and 5 present the distribution of Mental and Motor age scores, respectively, by chronological age up to CA 60 months in our sample. Each circle represents at least one test result of that particular value. The thin lines are the regression lines from our total sample and the dark lines the expected Mental and Motor age scores of the Bayley standardization sample. The mean values of the Boston sample are symbolized by black bars. Reed et al. administered the Bayley Scales at 6, 12, 18, 24, 30 and 36 months. Each mean value represents the assessments of 75-83 Down Syndrome children studied longitudinally. These means are very close to the regression lines derived from our total sample.

It seems, then, that young Down syndrome children, as a group, are very similar across countries.

Analysis at group level: linear or curvilinear growth lines?

The regression lines for the first 30 and the second 30 months of life seem to corroborate the conclusion that the development of DS children in the first two and a half years equals about half their chronological age and decreases somewhat thereafter (Tables 5a and 5b). Testing effects seem to be minimal since the results of children who were assessed the first time did not differ appreciably from the results of all test protocols that also included repeated testings. The change in slope of the growth curves appears to be more pronounced with the Mental than with the Motor Scale.

Curve fitting procedures were then applied to the Mental Scale scores using linear and logarithmic formulars. The best fit with $R^2 < .78$ was reached with the linear formula

$$MA'(DS) = 0.43 CA + 3.2 \text{ months.}$$

Table 5a: Regression of Mental age on CA

Age range	Assessment	Cases	Intercept	Slope
0 - 30 months	1st	193	.75	.56
	all	578	1.22	.57
31 - 61 months	1st	28	10.53	.29
	all	94	9.05	.30

Table 5b: Regression of Motor age on CA

Age range	Assessment	Cases	Intercept	Slope
0 - 30 months	1st	178	1.29	.46
	all	536	1.44	.48
31 - 61 months	1st	28	7.22	.32
	all	103	8.18	.33

This formula comes very close to that suggested by Berry et al. (1984). Figure 6a illustrates the result.

A logarithmic formula, however, fits the data nearly as well ($R^2 < .71$) The best logarithmic approximation was

$$MA'(DS) = 70.6 * \ln(CA) - 7.39 \text{ (see Figure 6b).}$$

Since it appears illogical to have DS children start life after birth at an advanced level of three months, as the linear model implies, a logarithmic function seems to be more appropriate at this early age. A developmental delay at birth by seven months, however, is equally illogical since these children are not born as embryos. This early period has therefore to be modelled differently. A possible solution could be a representation by different linear growth curves for the first few months and for the later months with the switch from one line to the second being established by optimization procedures. A theoretical foundation for such a change in growth gradient relative to healthy children is, however, problematic. We know, for instance, too little of the equivalent in DS children of the three-months shift observed in normal children (Rauh 1987); does it also happen in similar extent in DS children, and if so, at the same chronological or

the same developmental age ? At later ages, anyway, the linear function seems to represent the developmental data of DS children quite well.

The major lesson learned from these results is that statistical analyses can only partially help us with our decision between theoretical models. It seems, however, to be more parsimonious as well as psychologically appropriate to expect continued development in DS children as expressed by a linear model.

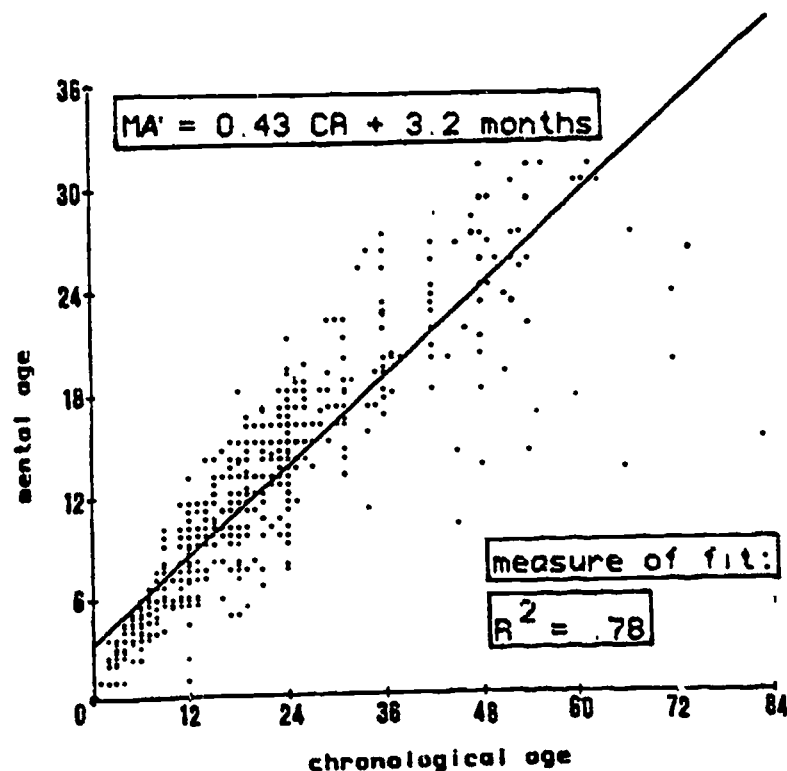


Fig. 6a: Fitting a linear model to the total of all assessments

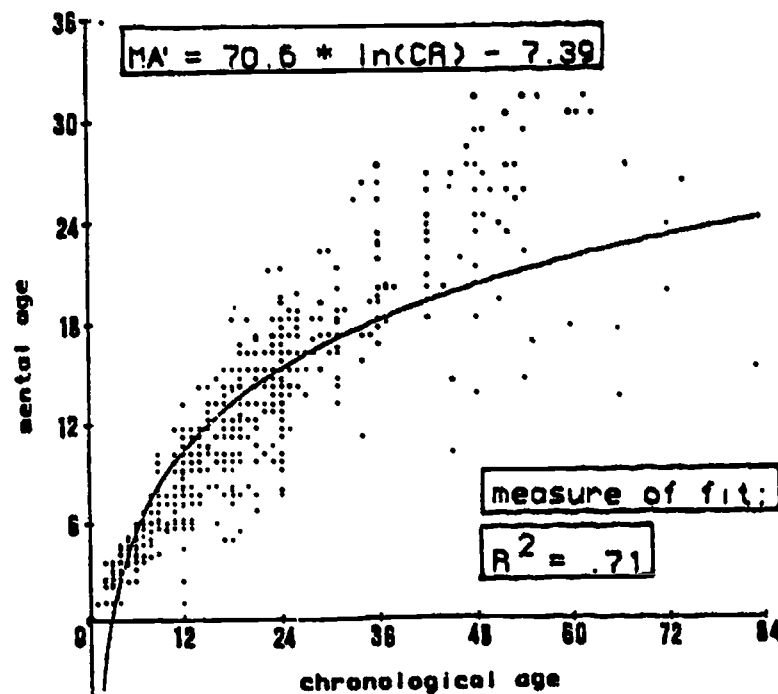


Fig. 6b: Fitting a logarithmic model to the total of all assessments

Interindividual variation

Figure 7 represents the means, the standard deviation around the means, and the total variation of Mental scores of the DS sample, transformed into Mental ages. For convenience of analysis, children below 30 months of age were put into three-monthly groups and into half-yearly groups thereafter. The means of the Boston study are again represented by black bars; they fall well onto the line of mean scores of our study. For comparison, the data of the normal standardization samples were similarly transformed into Mental ages and are illustrated in Figure 8a. The mean there is by definition a straight line. According to the Bayley Manual, the values representing three standard deviations around the mean were rarely ever reached empirically by a child of the respective age group. For convenience of comparison, the data of the DS children were squeezed in such a way that the X-axis represents half the chronological age of these children, a rough estimate of their estimated mean Mental age at that particular chronological age (Figure 8b). The similarity of the curves in the normal and the DS group are, *prima vista*, striking.

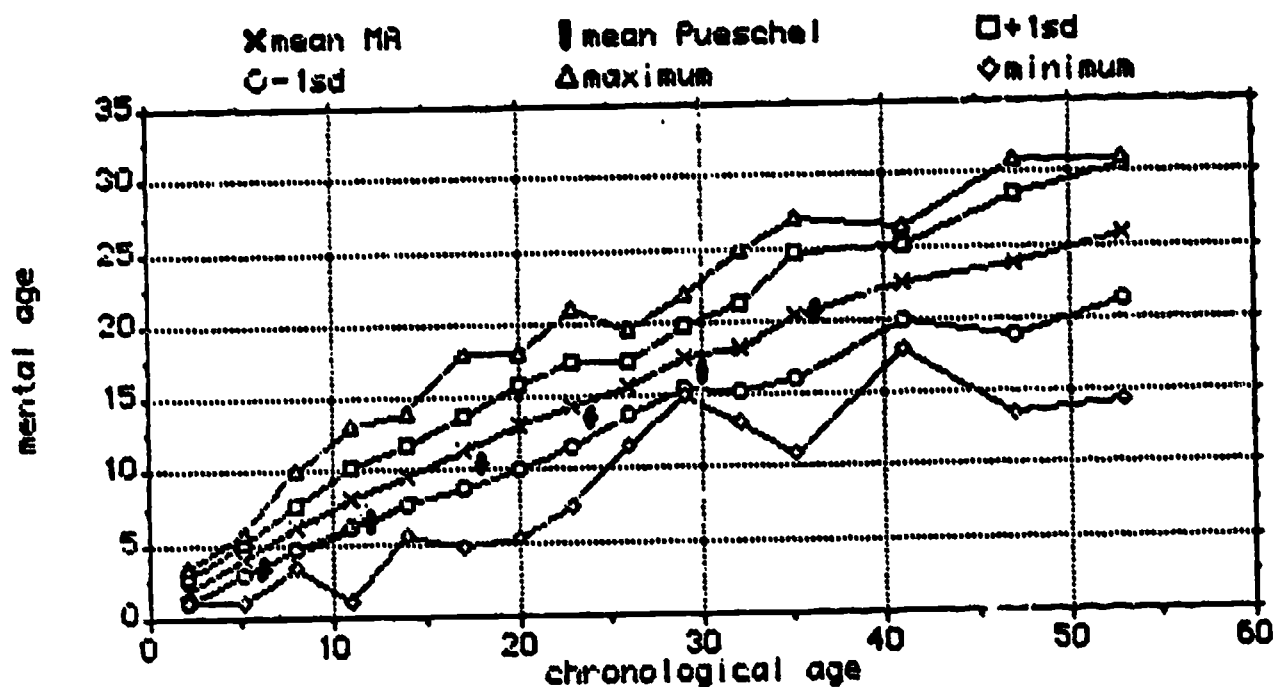


Fig. 7: Variation in Mental age scores relative to chronological age in Down syndrome children (n = 672 test protocols)

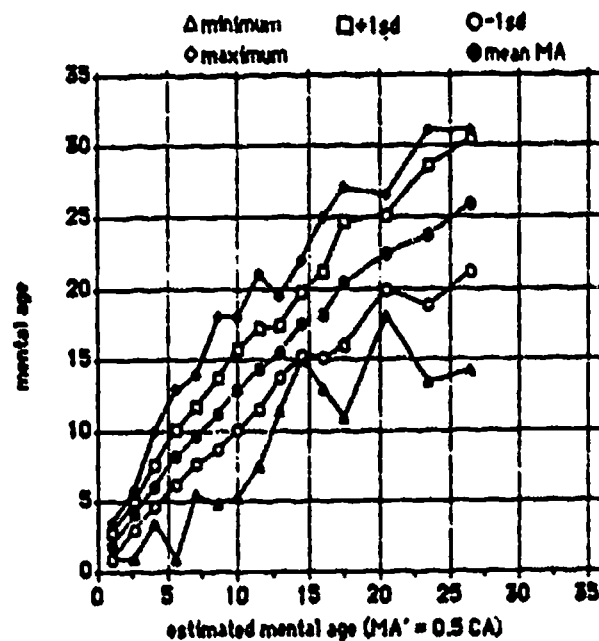
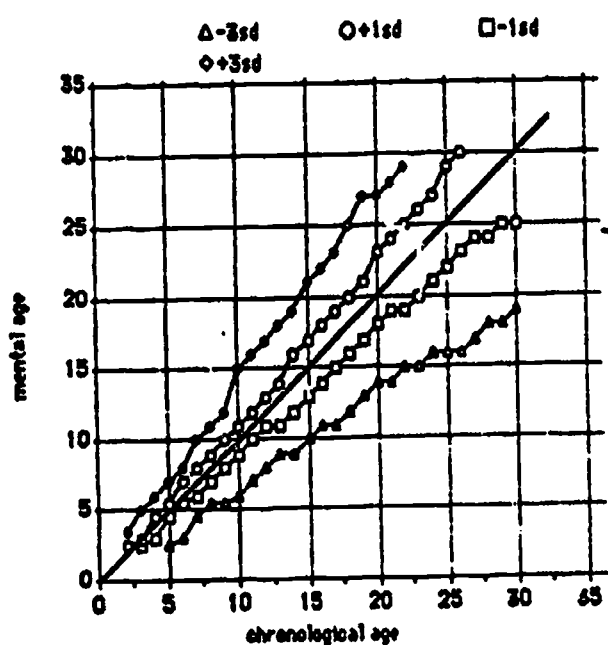


Fig. 8: Variation of Mental age scores

a) by chronological age

in the Bayley standardization sample (n = 1400)

b) by half the chronological age (estimated mean MA)

in the Down syndrome sample (n = 672 test protocols)

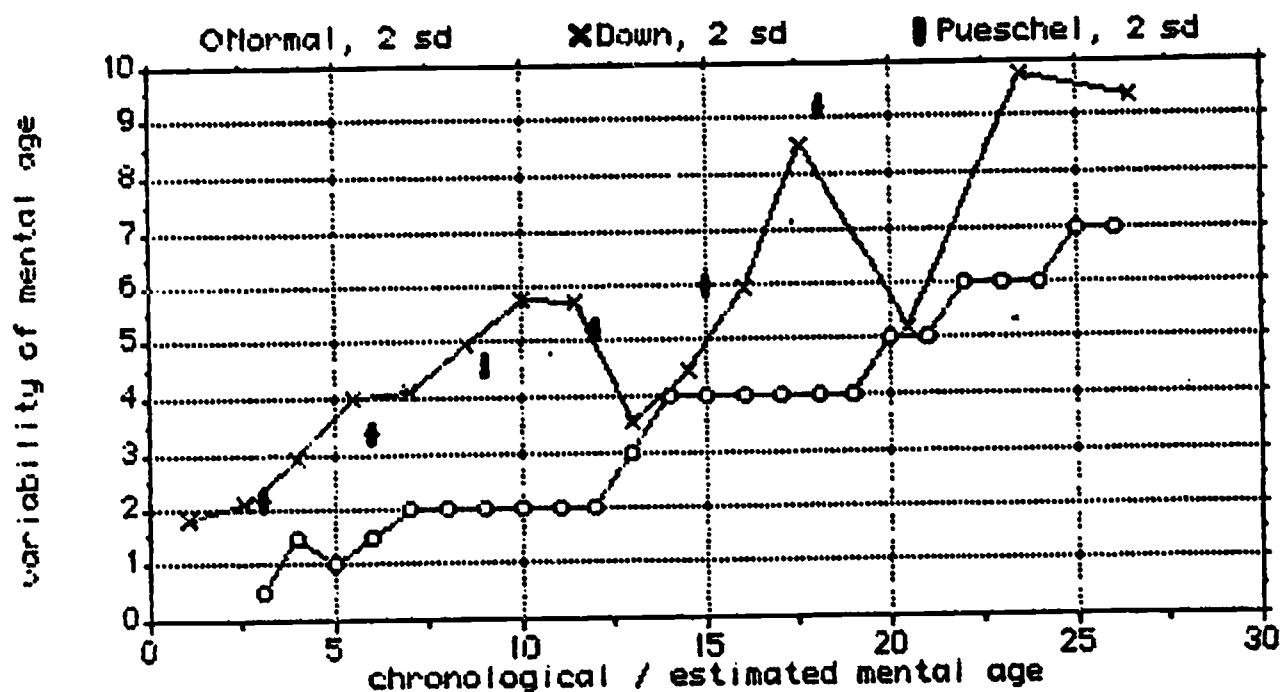
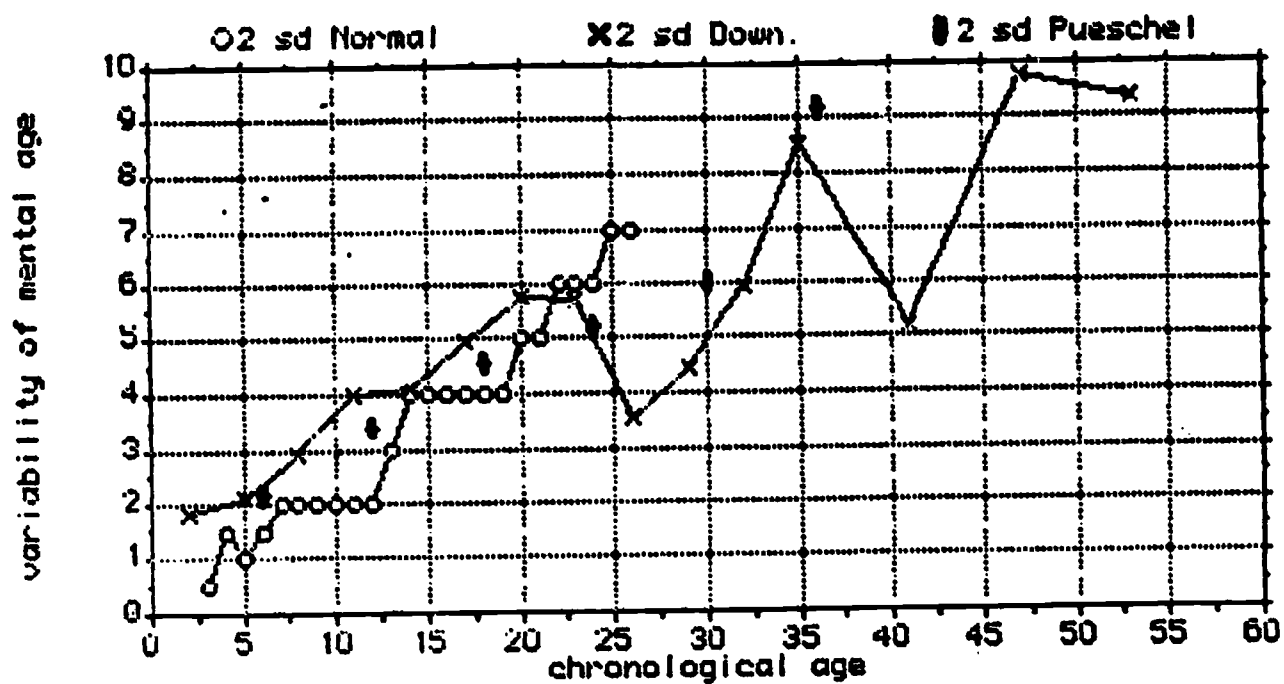


Fig. 9: Standard deviations in Mental age scores (x2) in the Bayley standardization sample, the Down syndrome sample and the Boston Down syndrome study.
a) by chronological age for all samples
b) by chronological age for the standardization and by half the chronological age (estimated mean Mental age) for the Down samples

Figures 9a and 9b depict the standard deviations (2SD) in the normal and in the Down syndrome groups, in Fig. 9a relative to their chronological age, and in Figure 9b with estimated mental age in the DS group as an equivalent to the chronological age in the standardization group. In both groups, variation increases with age, but more so in the normal group which starts out with very limited variation. In the DS groups, variation of test scores is already higher in the first 10 to 20 months than in the normal group, and this difference becomes even more pronounced when the groups are compared relative to their average performance level. The dips and peaks in the curves of our DS group still await further analysis and explanation. They may be due to sampling irregularities. The standard deviations in the Boston group that was studied longitudinally are also clearly above those of the standardization group, but more consistently so.

Although Down syndrome children being a clearly defined diagnostic group with a generally retarded development already in early childhood, an individual child's level of development can be estimated from his/her age only with large error variance. Their early development seems to be less closely monitored by biologically based "self-righting processes" than in children with normal karyotype. Our results are thus in accord with Kopp & McCall's description of the scoop model for DS children.

Individual growth paths

The large variation of test performances in the group of DS children could also reflect either a lack of reliability of testing or instability of individual growth patterns. Figures 10a and 10b demonstrate the individual growth patterns of those children from the Canadian and the Australian sample who were assessed with the Bayley Scales at least six times. The individual curves derived from the data points are largely continuous and seem to become differentiated in a fan-like form at a very early age (around 12 months), again substantiating the thesis of Kopp and McCall.

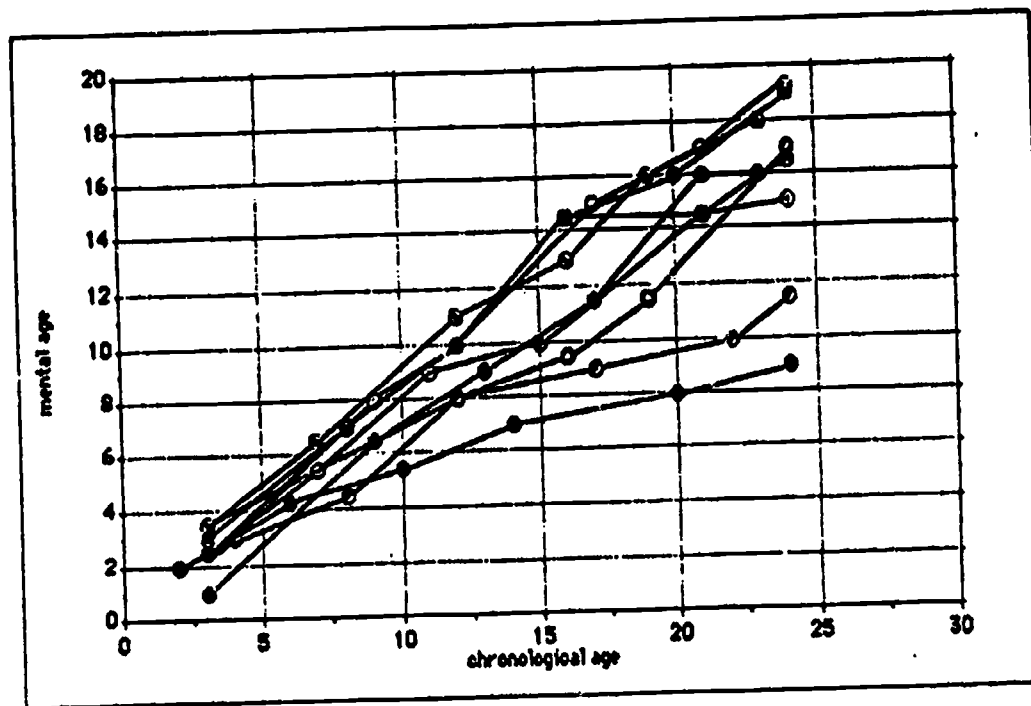


Fig. 10a: Individual growth curves of 9 Canadian DS children assessed at least six times

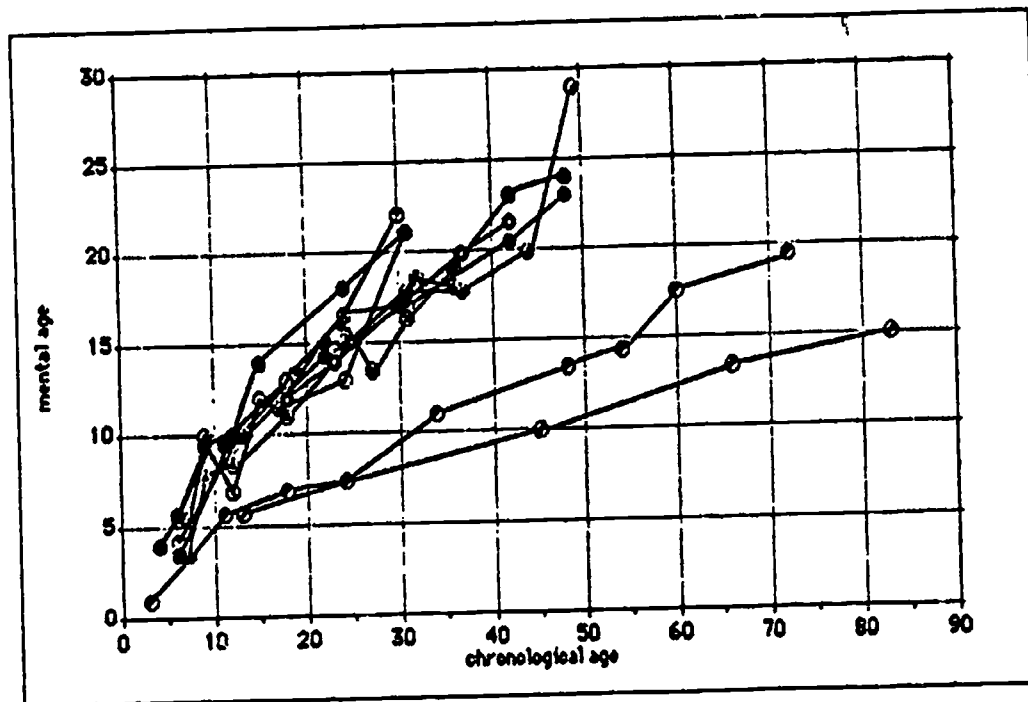


Fig. 10b: Individual growth curves of 11 Australian DS children assessed at least six times

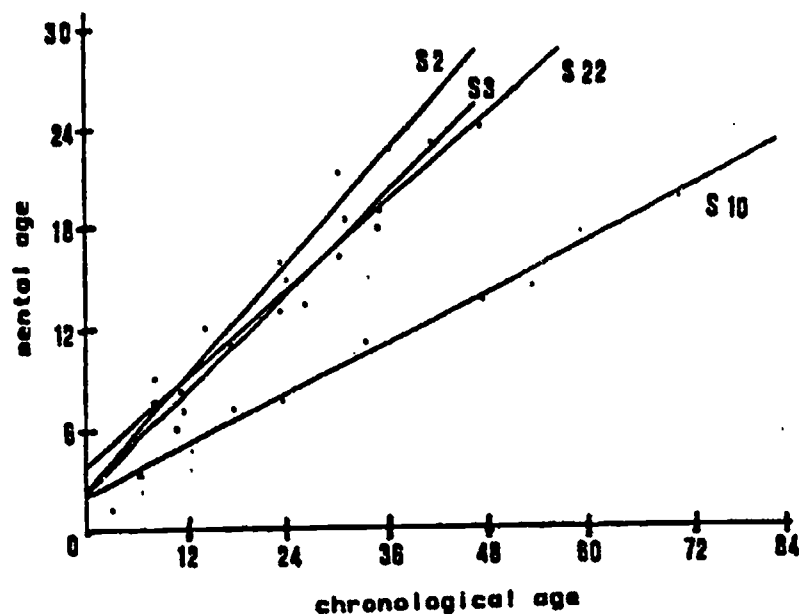


Fig. 11a: Examples of curve fitting with the longitudinal data of four Australian DS children (linear model)

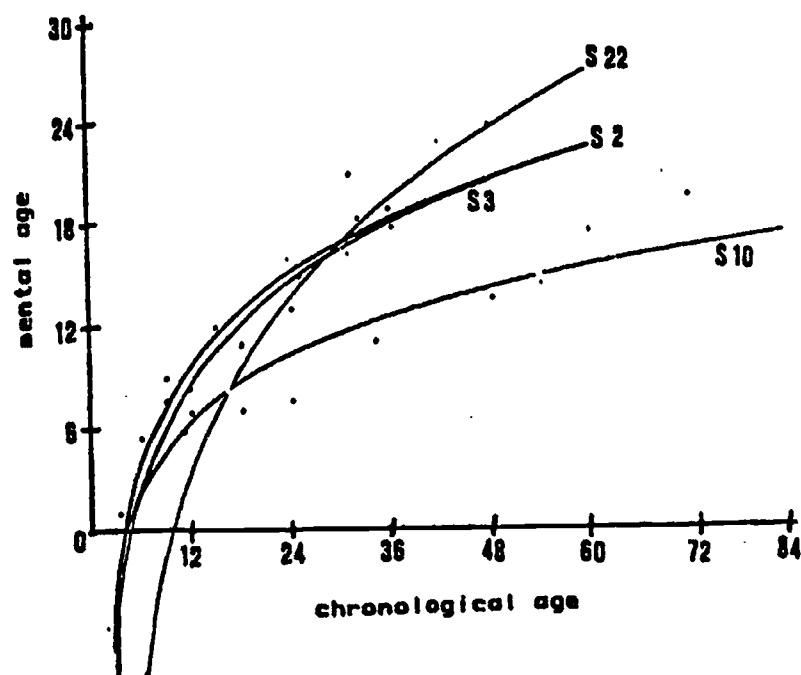


Fig. 11b: Examples of curve fitting with the longitudinal data of four Australian DS children (logarithmic model)

For four Australian subjects, linear and logarithmic functions were fitted to their data points. The results are shown in Figures 11a and 11b. Again, measures of fit were equally high for both types of curves (R^2 between .80 and .90). When aggregating individual growth curves, the linear function fitted better with the Canadian children (ages 2 - 26 months) and the logarithmic function with the Australian children (ages 2 - 60 months). For an empirically based model decision, however, many more cases with many data points are needed.

Instead of using parametric measures, qualitative characteristics of growth curves such as linearity, monotonicity, flattening etc. can be sampled and analyzed. Procedures for estimating reliability, stability and developmental change in such a data set are being developed by Rudinger (1987). Such qualitative procedures seem to be better suited for the type of psychological data available and seem to represent the status and the degree of precision of developmental theories and models more adequately. Such analyses with the present Bayley data will be reported in a forthcoming paper.

Conclusion

With DS children, Bayley tests can and should be used beyond the standardization age of 30 months as long as the test captures the performance of the child. This will be, on average, up to nearly 60 months of age.

The 707 test protocols of 229 Down syndrome children did not empirically dictate a specific theory of developmental progression. Linear and logarithmic models can be fitted equally well. This is true at the group level as well as at the individual level. A logarithmic model appears theoretically more appropriate at the earlier age level when developmental progression is expressed largely by sensorimotor achievements, and a linear model thereafter. Over shorter age spans, how-

ever, a linear model seems to be more adequate, and over longer ones a logarithmic model. Methods that aggregate individual growth patterns according to their qualitative characteristics seem to be more appropriate to test different developmental models.

The most striking result was the large variation of mental and motor performances in Down syndrome children already at a very early age, sometimes twice as large as in the normal sample. DS children seem to be more different from each other at any particular age than are unselected children of normal karyotype. Instead of being more controlled by biological factors than a normal child, as is for instance implied when the behavior of these children is interpreted as being instinct driven and instinct guided (Rett 1977), these children seem to be less "protected" biologically and more at the mercy of additional health handicaps and the quality of their learning environments. If this holds true, then parents of DS children have no time to adapt to their parental tasks as they may have with healthy children (Rauh 1986, 1987), but have to be perfect from the beginning. Whereas normal children sometimes develop despite of their parents' mistakes, these children do not seem to be equipped with adequate "self-righting processes". They, then, also pose the most rigorous test to developmental psychologists' theories regarding necessary and sufficient structures and mechanisms of development.

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